

BRAIN ARTERIES MOVEMENT DETECTION WITH GATED GRADIENT ECHO SEQUENCE: STANDARDIZATION, REGISTRATION AND SUBTRACTION OF SERIAL MAGNETIC RESONANCE IMAGES.

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Abstract—In order to make evident pulsing brain arteries movements associated with heart activity, intramodality MR registration and subtraction has to be used to detect small differences between serial MR brain images. A new voxel-based rigid-body registration algorithm, including: (1) a standardization of grey levels procedure by means of similarity measure optimisation, (2) a new full 2-D convolution cubic interpolation zooming procedure, (3) a low computational cost multi-scale iterative procedure, that uses the zoomed versions of images to be registered, is proposed. It allows up to 1/8 pixel accuracy.

Keywords - registration, zooming, multi-scale.

I. INTRODUCTION

Our purpose is to put into evidence pulsing brain arteries movements associated to heart activity. In order to detect these small changes from serial MR images sequences, image subtraction has to be used. Unfortunately, non-stabilized steady-state during heart gated MR acquisition, distortions in the geometry and grey scale variations within serial images are observed. Detection of the small changes in brain image is then difficult by direct image subtraction. Consequently, subtraction must be preceded by a registration step that uses a similarity criterion to optimise image-to-image matching.

Several techniques of intra-modality rigid-body MR image registration with sub-pixel accuracy have been proposed in the past [1], [2]. Sometimes, the registration is recommended to be performed after a preliminary segmentation [3], but several disadvantages exist [4], [5]: (1) it neglects the fact that the high-frequencies are filtered during segmentation, loosing registration performance, that allows the most accurate detection of the geometrical artefact modifications; (2) it imposes the necessity of a preliminary standardization procedure [6], in order to ensure that the same grey levels have the same tissue meaning.

We propose here a new automated full-image registration algorithm ZSRTSR (Zooming, Scaling, Rotation, Translation, Similarity test and Reformatting), where all the geometrical transformations - Rotation, Translation or Scaling - are applied to the (same and initially produced) zoomed versions of the standardised images within the MR sequence. This allows the sub-pixel accuracy with computational decreasing cost.

II. METHODOLOGY

The algorithm is divided in the two following steps:

(1) the image standardization – it transforms the sequence into uniform grey level scale, using one of the slices, generally the best contrasted, as a reference. It guarantees that grey levels have similar tissue meaning within the sequence, making possible inter-slice comparison.

(2) the image registration – it transforms geometrically each slice until a measure of similarity [7] with the chosen-to-be-reference slice is maximised. On the contrary of previous suggested treatment order [3], as STRICTER protocol: Segmentation, Translation, Rotation, Interpolation, Chi-squared Test and Reformatting, using ZSRTSR we take advantage of pre-interpolated images, adopting the following steps: (eventually Scaling), Rotation, Translation, directly performed, as can easily be seen, with sub-pixel accuracy. The scaling transform is necessarily to be added in order to diminish artefacts due to the non-linearity in amplitude of the phase coding gradient.

The algorithm performs:

For [all the scaled versions produced within a given value interval of scaling coefficient] perform [all the rotations, by using a rotational given step, within a given interval of values]. For [each of the rotated versions] perform [all the translations, by using a given translation step, within a given interval of values]. For [each image obtained after the conjugate transform of scaling, rotation and translation] a similarity comparison with the reference image should be done. When the best measure of similarity (listed below) [7] is obtained, the image is to be considered the best registered version.

The quantity of computation is severely reduced [8] (until 8 times, comparing with the all-positions technique) by:

- (1) an automatic robust detection of the “good” directions of the scaling and rotation, for which the measure of similarity is increasing, avoiding unusable computations in the “wrong” directions;
- (2) the multi-scale approach: the algorithm finds the best position first in the (x1) zoomed image, then it passes to the (x2) zoomed version, performing the calculus only in the neighbourhood of the anterior (x1) found-to-be best position, and so on.

Several similarity criteria have been used: Sum of Absolute Differences, Correlation, Cross-correlation,

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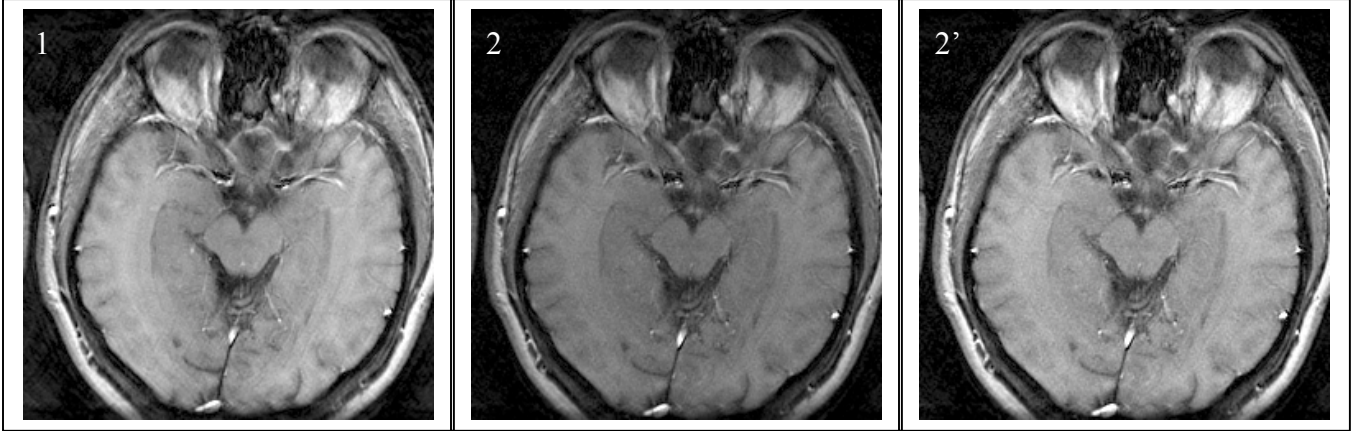


Fig. 1. The images (1) and (2) represent the first and the fourth slices within the gated Gradient Echo MR sequence. The effect of grey level standardisation by using (1) as reference slice can be observed comparing the new obtained image (2') with the original slice (2).

Levenburg-Marquardt. The last one has been mostly preferred, proving robustness and low computational cost.

Several methods of interpolation, as Nearest Neighbour (NN), Bilinear Interpolation (BI), Cubic B-Spline (CBS) and Cubic Interpolation (CI) have been used. Due to the fact that the quality of the registered image is strongly dependent on the quality of the zooming procedure, a new optimized Cubic Interpolator is proposed and a new fully 2D zooming convolution cubic kernel, to ensure good utilisation of spatial information within the image, has been designed [9].

III. RESULTS

The algorithm was applied to a gated Gradient Echo MR sequence ($T_{R\text{ eff}} = 46\text{ms}$, 15 phases, 1 slice; $T_{R\text{ real}} = \text{R-R}$ (gated acquisition); $T_E = 8$ (half echo); $\alpha = 35^\circ$; $\text{FOV} = 19$; $\text{Matr.} = 256^2$; $\text{Tck.} = 9$). As a characteristic of this protocol, during heart gated acquisition, a non-stabilised steady-state is always present. Consequently, a decrease in contrast takes place within the sequence, tending asymptotically to an equilibrium position.

■ Standardization.

In this paper we considered for illustration two slices within the sequence, the first – denoted by (1), and the fourth – denoted by (2). As can be easily observed, (1) is better contrasted than (2) (see fig. 1). Performing the grey level standardization, the contrast of image (2) was compensated (2').

■ Interpolation.

Simulations of several 2-D zooming convolution kernels have been performed. The task was to model the MR scanner acquisition at simple and zoomed ($\times 1$) scale by means of interpolation [10]. Considering an 256^2 image we first decimate it: for each four neighbours produce a new pixel equal to the mean value. We so obtain 128^2 images of less than 25% information as the initial one. We verified that these new decimated images are similar to half resolution acquired MR images. We proved that this averaging by decimation

procedure represents a good model of physical process performed by MR scanner during acquisition. Consequently, the challenge was to produce by interpolation, from the new 128^2 data, a new 256^2 image as similar as possible of the original 256^2 one.

We compared the three zooming interpolation 2D kernels methods, Cubic B-Spline, Pyramide and a new optimised 16-neighbours Cubic Interpolator. We produced the difference-images between the original (2') one and the new interpolated images (see fig. 2, images 3, 4 and 5). The new Cubic Interpolator showed the best performance, most visible at the level of high-frequencies (Levenburg-Marquardt similarity measure ratio (3):(4):(5) is 220:169:122).

■ Registration.

The registration of zoomed image (2') with (1) was performed. The image-difference between the reference image (1) and the new registered one was produced (10). We compared it with the image-difference between the unmodified slices after the acquisition (8), and also, with the image-difference between the standardized images (9).

After both standardization and registration conjugate procedure (10), the image-difference presents a measurable amelioration (see fig 3., the difference similarity measure ratio (8):(9):(10) is 1666:498:281).

IV. DISCUSSION

Because the purpose was to put into evidence pulsing brain arteries movements associated to heart activity (even if not a quantification of this movement, for the moment), the visible reduction of mismatch artefact between the images proved the validity of the registration algorithm. In the image-difference obtained after both standardization and registration conjugate procedure (10), movements up to several pixels (1 pixel is about 0.8 mm) could be observed.

The new cubic interpolator showed at least 25% amelioration in comparison with other techniques. The visible decreasing of the computational cost and the quality of

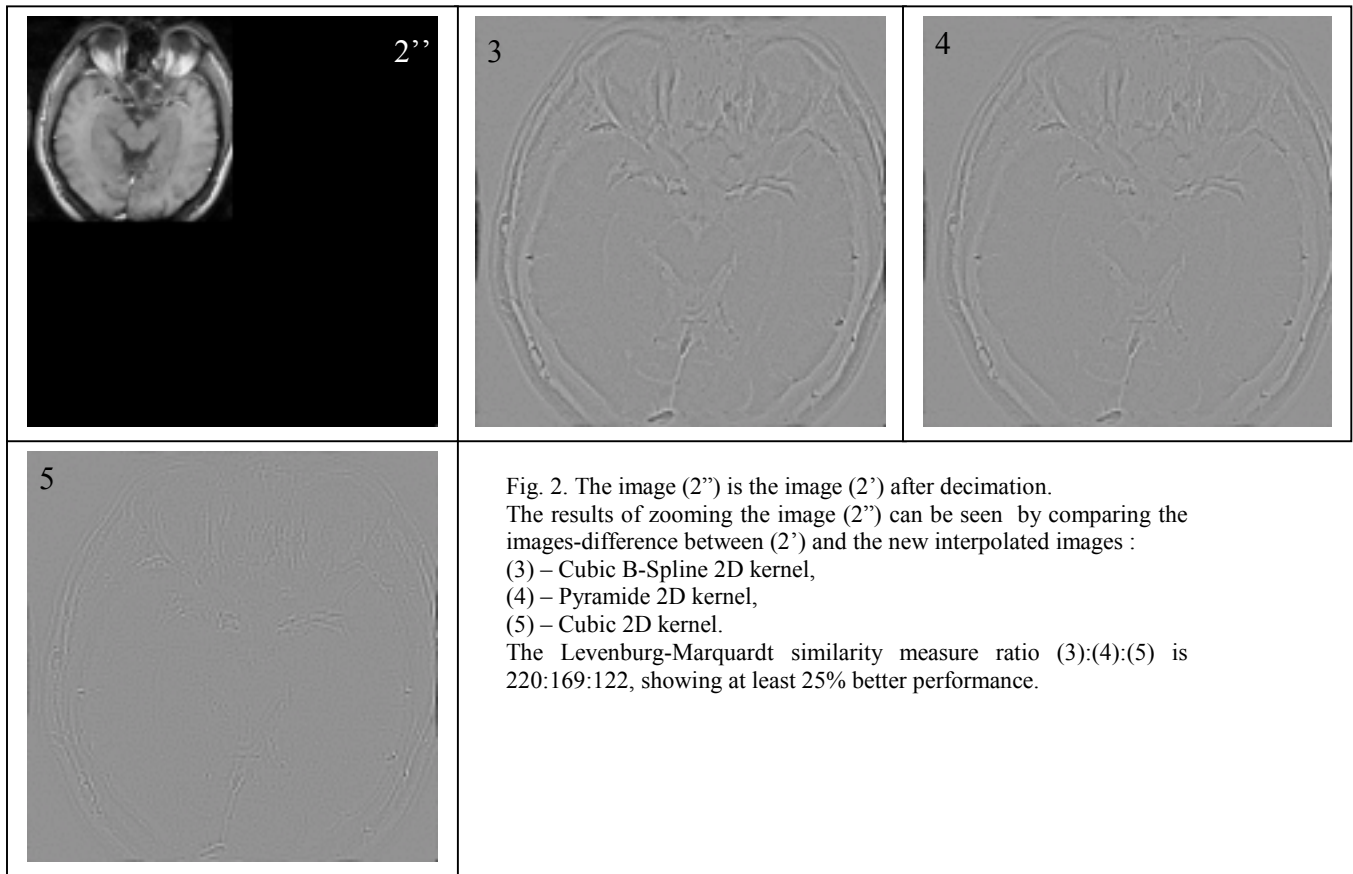
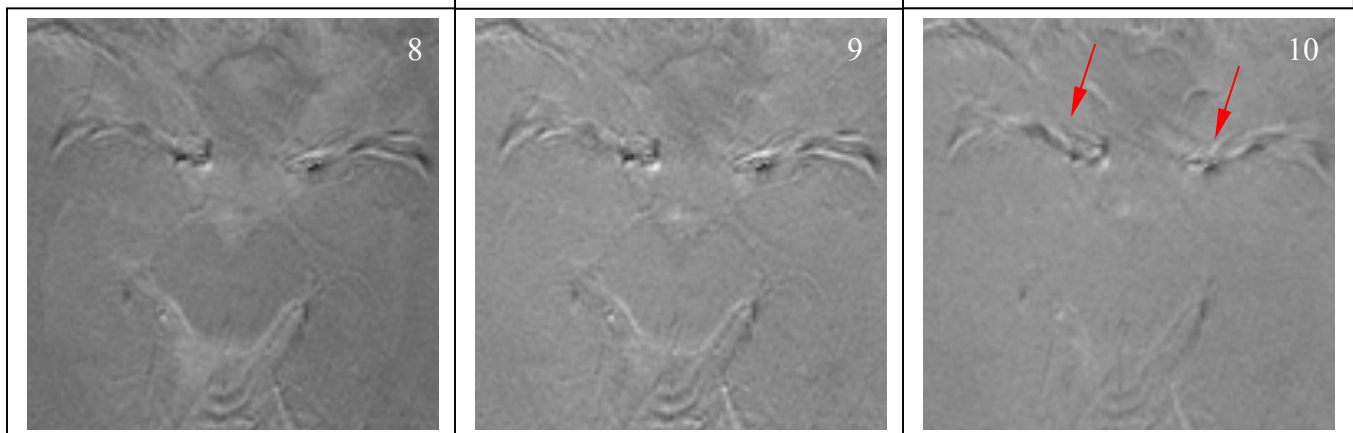


Fig. 3. The images (6) and (7) are the (x1) zoomed versions of the images (1), respective (2').
 The effect of registration and standardisation can be seen comparing the images-difference :
 (6) - before both registration and standardisation,
 (7) - after (only) the standardisation,
 (8) - after both standardisation and registration.



registration until 1/8 pixel make this algorithm to be at least competitive with the other published ones.

V. CONCLUSION

A new full-image registration algorithm ZSRTSR, using standardized and zoomed images by a new zooming interpolation technique, that allows visible high-frequency amelioration, was proposed. Comparing the registered slices of a gated Gradient Echo MR sequence, it becomes possible to better distinguish the brain arteries regular movements associated to the heart activity (see fig. 3, image 10).

REFERENCES

- [1] Raymond J. Althof, Marco G. J. Wind, James T. Dobbins, "A Rapid and Automatic Image Registration Algorithm with Subpixel Accuracy", *IEEE Trans. Med. Imaging*, vol.15, p. 768, June 1997.
- [2] Kotsas P, Malasiotis S, Strintzis M, Piraino DW, Cornhill JF, "A fast and accurate method for registration of MR images of the head", *Int J. Med. Inf.*, pp. 167-182, Oct.-Dec.1998.
- [3] William G. Bradley Jr. and Graeme M. Bydder, "Advanced MR Imaging Techniques", ed. Mosby, pp. 221-280, 1997.
- [4] Jamal Imran, "Estimation des variations de température par IRM: optimisation des conditions expérimentales et de la précision des mesures", PhD thesis, Université de Technologie de Compiègne, 2000.
- [5] Jamal Imran, François Langevin, Hervé Saint-Jalmes, "Two-point method for T_1 estimation with optimised gradient-echo sequence", *Magn. Reson. Im.*, Vol. 17, No. 9, pp. 1347-1356, 1999.
- [6] L. G. Nyul, J. D. Udupa, "On standardizing the MR image intensity scale", *Magn. Reson. Med.*, vol. 42, pp. 1072-1081, 1999.
- [7] T. M. Buzug, J. Weese, "Voxel-Based Similarity Measures for Medical Image Registration in Radiological Diagnosis and Image Guided Surgery", *Journal of Comp and Inf. Tech*, vol. 6, no.2, , pp. 165-179, June 1998.
- [8] Jean-Philippe Didon, "Recalage d'images cerebrales en IRM : application à la pathologie tumorale et vasculaire", PhD thesis, Université de Technologie de Compiègne, 1996.
- [9] Razvan Ionescu, "Detection et rehaussement des informations en imagerie medicale: application en IRM sequentielle à la detection après réalignement de signaux faibles", PhD thesis, Université de Technologie de Compiègne, September 2001.
- [10] Thomas M. Lehmann, Claudia Gonner and Klaus Spitzer, "Survey: Interpolation Methods in Medical Image Processing", *IEEE Trans. Med. Imaging*, vol. 18, no. 11, pp. 1049-1075, November 1999.